# Rapid, non-invasive measurement of gastric emptying rate using transcutaneous fluorescence spectroscopy: supplement

AARON M. LETT,[1] ALEXANDRA LIM,[1] CHARLOTTE SKINNER,[1] JAMES MAURICE,[2] NIKHIL VERGIS,[1] ARA DARZI,[2,3] ROBERT GOLDIN,[1] MARK THURSZ,[1] AND ALEX J. THOMPSON[2,3,*] (iD)

[1]*Department of Metabolism, Digestion and Reproduction, Imperial College London, W2 1NY, UK*
[2]*Department of Surgery & Cancer, St. Mary's Hospital Campus, Imperial College London, W2 1NY, UK*
[3]*The Hamlyn Centre, Institute of Global Health Innovation, South Kensington, Imperial College London, SW7 2AZ, UK*
[*]*alex.thompson08@imperial.ac.uk*

# Rapid, non-invasive measurement of gastric emptying rate using transcutaneous fluorescence spectroscopy: supplementary information

AARON M. LETT[1], ALEXANDRA LIM[1], CHARLOTTE SKINNER[1], JAMES MAURICE[2], NIKHIL VERGIS[1], ARA DARZI[2, 3], ROBERT GOLDIN[1], MARK THURSZ[1], ALEX J. THOMPSON[2, 3*]

[1]*Department of Metabolism, Digestion and Reproduction, Imperial College London, W2 1NY, UK*
[2]*Department of Surgery & Cancer, St. Mary's Hospital Campus, Imperial College London, W2 1NY, UK*
[3]*The Hamlyn Centre, Institute of Global Health Innovation, South Kensington, Imperial College London, SW7 2AZ, UK*
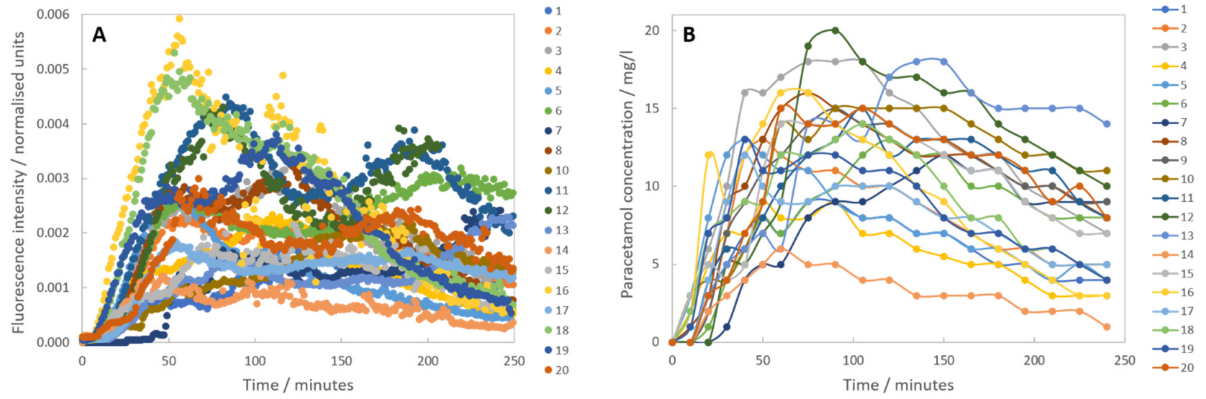
* *alex.thompson08@imperial.ac.uk*

**This PDF file includes:**

Supplementary Figures S1-S6

Supplementary Table S1

## Supplementary Figures



**Figure S1.** Fluorescence intensity and paracetamol concentration data for all participants included in the study. **(A)** Fluorescence intensity as a function of time. Data for participant 9 is excluded due to an error in the fluorescence data collection. **(B)** Paracetamol concentration as a function of time for all study participants. For all participants, the liquid test meal was fully consumed within the first 3 minutes of the experiments.
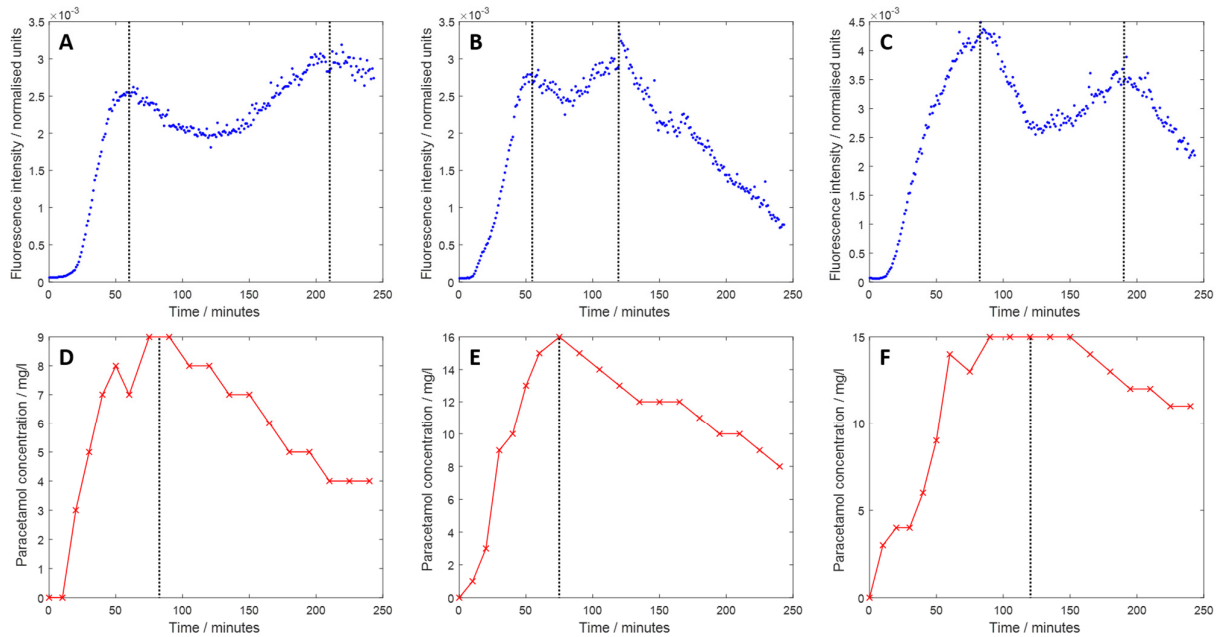


**Figure S2.** Manual identification of peak times in fluorescence **(A-C)** and paracetamol **(D-F)** data. Vertical dotted lines indicate identified peaks. **(A-C)** Exemplar fluorescence vs. time curves for participants 6 **(A)**, 8 **(B)** and 11 **(C)**, demonstrating the presence of two peaks. **(D-F)** Exemplar paracetamol concentration vs. time curves for participants 1 **(D)**, 8 **(E)** and 10 **(F)**, in which only a single peak is observed.
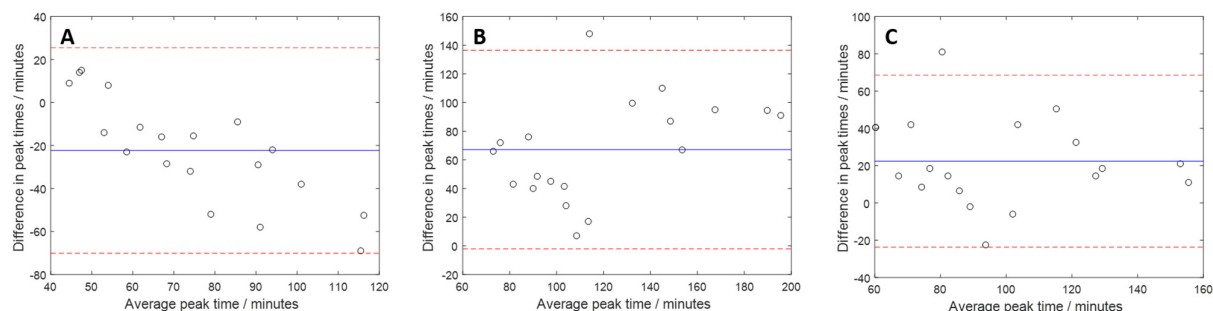
**Figure S3.** Bland-Altman plots comparing the fluorescence and paracetamol peak times. Plots show the difference in peak times (between the fluorescence and paracetamol values) against the average (mean) of the peak times for: **(A)** the 1st fluorescence peak; **(B)** the 2nd fluorescence peak; and **(C)** the mean of the two fluorescence peak times. Large differences in peak times (> 20 minutes) are observed in all cases, and a clear trend is observed in **(A)** where higher peak times correlate with larger time differences. Data for participant 9 is excluded due to an error in the fluorescence data collection.
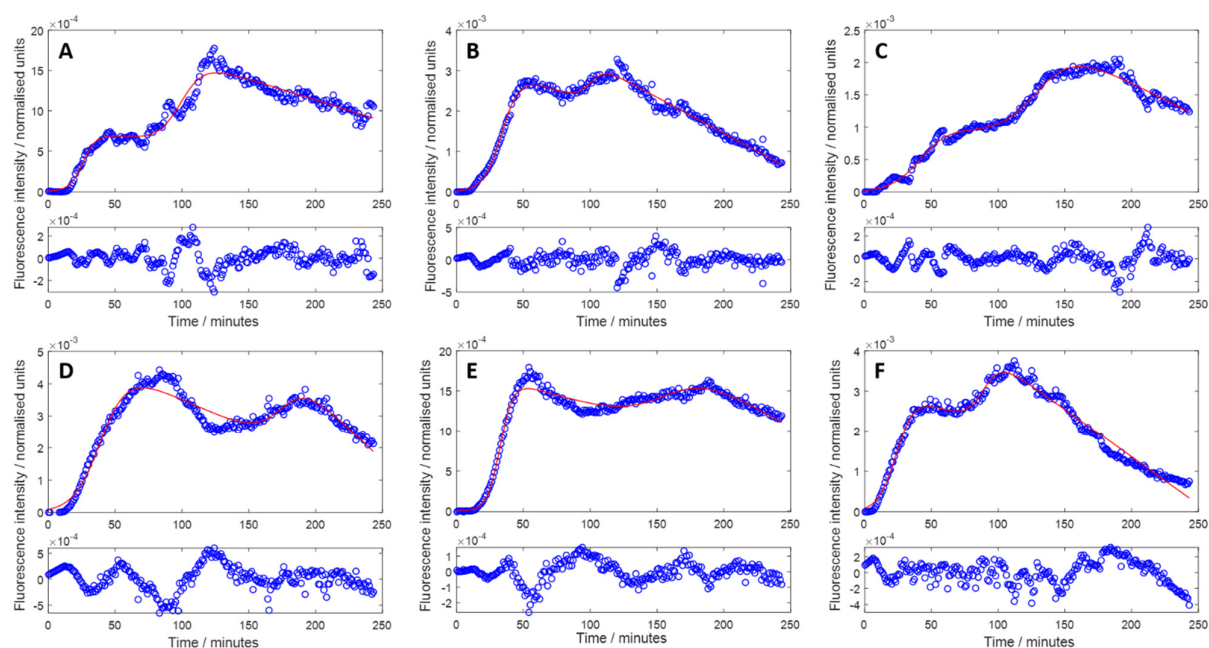


**Figure S4.** Example fitted fluorescence vs. time curves. Upper plots show the fluorescence intensity data (blue circles) and the fit curves (solid red lines). Lower plots show the residuals (i.e. the difference between the fitted value and the data at each time point). Good fits are observed in all cases ($R^2 > 0.85$), and the residuals are generally randomly distributed around zero. **(A-F)** Data for participants 1, 8, 10, 11, 17 and 19 respectively. Graphs shown in **(D)** and **(E)** represent examples where imperfections are noticeable in the fits. Even in these examples, good fitting is observed at most time points and $R^2$ values remain above 0.85. Also see further details in Table S1 below.
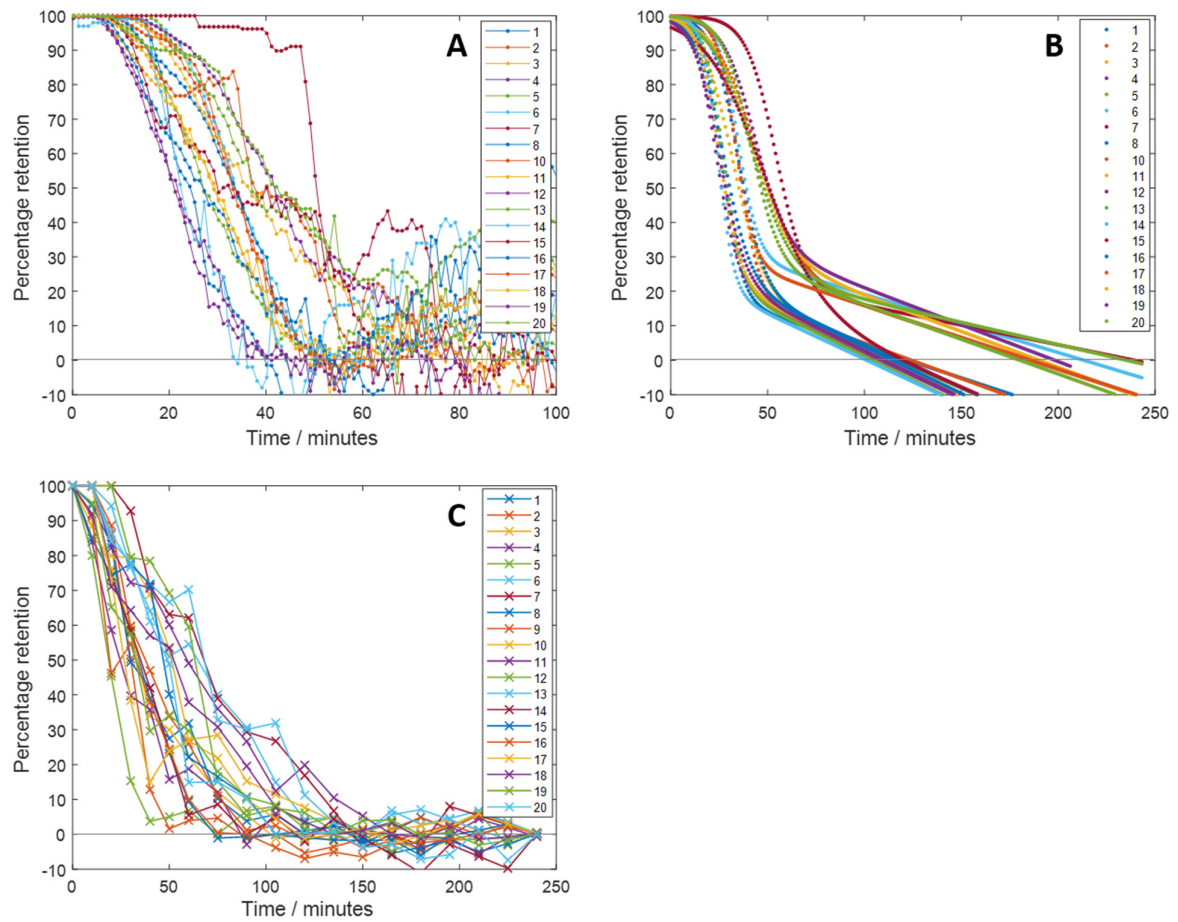
**Figure S5.** Percentage retention as a function of time for all participants included in the study. **(A)** Fluorescence percentage retention vs. time calculated according to the direct method. **(B)** Fluorescence percentage retention vs. time calculated according to the fitting-based approach. **(C)** Paracetamol percentage retention vs. time calculated according to the method presented by Medhus *et al*. [1]. Data for participant 9 is excluded from **(A)** and **(B)** due to an error in the fluorescence data collection. In **(A)**, only the first 100 minutes of data are shown. This is because, using the direct method, retention values sometimes increase again after reaching zero due to the use of the first peak to determine the point at which the stomach is 100% empty.
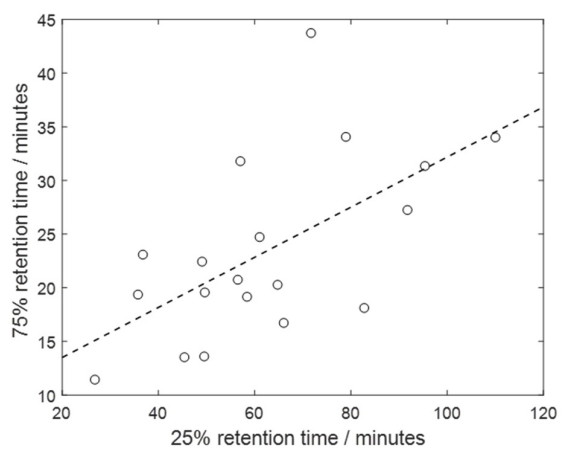
**Figure S6.** 75% paracetamol retention time as a function of 25% paracetamol retention time. The dotted line represents a linear regression to the data, clearly indicating a correlation between the 75% and 25% retention times.

## Supplementary Table

**Table S1**. Fitted parameters for the fitting-based method of analyzing the fluorescence data. Parameters shown are the variables defined in equations (2-5) in the main text along with the $R^2$ goodness of fit parameter. Units are shown in brackets. No units are given for $B_{max}$, $L_{max}$ and $R^2$ as these are unitless parameters ($B_{max}$ and $L_{max}$ are unitless as the fluorescence intensity data was normalized accordingly to laser power). Data for participant 9 is excluded from the Table due to an error in the fluorescence data collection.

| Participant number | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $B_{max}$ | $k_B$ (min$^{-1}$) | $t_{B½}$ (min) | $L_{max}$ | $k_L$ (min$^{-1}$) | $t_{L½}$ (min) | $C$ (min$^{-1}$) | $R^2$ |
| 1 | 0.0008 | 0.20 | 26.20 | 0.0014 | 0.12 | 99.94 | 0.0024 | 0.96 |
| 2 | 0.0025 | 0.19 | 34.59 | 0.0008 | 0.10 | 120.38 | 0.0028 | 0.99 |
| 3 | 0.0031 | 0.12 | 31.16 | 0.0021 | 0.13 | 97.80 | 0.0034 | 0.95 |
| 4 | 0.0015 | 0.17 | 23.00 | 0.0020 | 0.10 | 81.96 | 0.0038 | 0.98 |
| 5 | 0.0027 | 0.20 | 26.74 | 0.0000 | 0.00 | 42.10 | 0.0039 | 0.94 |
| 6 | 0.0028 | 0.19 | 34.33 | 0.0047 | 0.06 | 182.16 | 0.0026 | 0.99 |
| 7 | 0.0017 | 0.13 | 53.92 | 0.0024 | 0.08 | 218.34 | 0.0016 | 0.96 |
| 8 | 0.0034 | 0.15 | 34.27 | 0.0016 | 0.18 | 100.49 | 0.0036 | 0.98 |
| 10 | 0.0012 | 0.09 | 43.14 | 0.0026 | 0.07 | 130.95 | 0.0028 | 0.98 |
| 11 | 0.0054 | 0.10 | 40.15 | 0.0062 | 0.10 | 176.83 | 0.0034 | 0.95 |
| 12 | 0.0051 | 0.12 | 42.50 | 0.0082 | 0.14 | 177.20 | 0.0037 | 0.95 |
| 13 | 0.0015 | 0.10 | 41.06 | 0.0027 | 0.09 | 216.77 | 0.0019 | 0.97 |
| 14 | 0.0009 | 0.25 | 24.22 | 0.0005 | 0.02 | 89.14 | 0.0036 | 0.86 |
| 15 | 0.0022 | 0.07 | 44.98 | 0.0011 | 0.11 | 122.00 | 0.0034 | 0.90 |
| 16 | 0.0059 | 0.14 | 26.30 | 0.0000 | 0.00 | 74.81 | 0.0039 | 0.86 |
| 17 | 0.0018 | 0.20 | 32.98 | 0.0017 | 0.06 | 159.75 | 0.0028 | 0.98 |
| 18 | 0.0038 | 0.18 | 24.64 | 0.0022 | 0.28 | 39.99 | 0.0038 | 0.97 |
| 19 | 0.0033 | 0.15 | 24.38 | 0.0028 | 0.15 | 89.66 | 0.0039 | 0.98 |
| 20 | 0.0029 | 0.14 | 40.79 | 0.0028 | 0.11 | 166.06 | 0.0032 | 0.95 |
| **Mean** | 0.0028 | 0.15 | 34.18 | 0.0024 | 0.10 | 125.60 | 0.0032 | 0.95 |
| **Standard deviation** | 0.0015 | 0.05 | 8.77 | 0.0020 | 0.07 | 53.61 | 0.0007 | 0.04 |

# References

1.	A. W. Medhus, O. Sandstad, J. Bredesen, and E. Husebye, "Delay of gastric emptying by duodenal intubation: Sensitive measurement of gastric emptying by the paracetamol absorption test," *Alimentary Pharmacology & Therapeutics*, **13**(5), 609-620 (1999)